

ONLINE FIRST

Eliminating Preventable Death on the Battlefield

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Objective: To evaluate battlefield survival in a novel command-directed casualty response system that comprehensively integrates Tactical Combat Casualty Care guidelines and a prehospital trauma registry.

Design: Analysis of battle injury data collected during combat deployments.

Setting: Afghanistan and Iraq from October 1, 2001, through March 31, 2010.

Patients: Casualties from the 75th Ranger Regiment, US Army Special Operations Command.

Main Outcome Measures: Casualties were scrutinized for preventable adverse outcomes and opportunities to improve care. Comparisons were made with Department of Defense casualty data for the military as a whole.

Results: A total of 419 battle injury casualties were incurred during 7 years of continuous combat in Iraq and 8.5 years in Afghanistan. Despite higher casualty severity indicated by return-to-duty rates, the regiment's rates of

10.7% killed in action and 1.7% who died of wounds were lower than the Department of Defense rates of 16.4% and 5.8%, respectively, for the larger US military population ($P = .04$ and $P = .02$, respectively). Of 32 fatalities incurred by the regiment, none died of wounds from infection, none were potentially survivable through additional prehospital medical intervention, and 1 was potentially survivable in the hospital setting. Substantial prehospital care was provided by nonmedical personnel.

Conclusions: A command-directed casualty response system that trains all personnel in Tactical Combat Casualty Care and receives continuous feedback from prehospital trauma registry data facilitated Tactical Combat Casualty Care performance improvements centered on clinical outcomes that resulted in unprecedented reduction of killed-in-action deaths, casualties who died of wounds, and preventable combat death. This data-driven approach is the model for improving prehospital trauma care and casualty outcomes on the battlefield and has considerable implications for civilian trauma systems.

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THE 75TH RANGER REGIMENT is the US Army's premier raid force. Comprising more than 3500 personnel, the regiment conducts joint special operations combat missions to include airborne, air assault, and other direct-action raids to seize key targets, destroy strategic facilities, and capture or kill enemy forces.¹ Providing care to casualties during such missions is a major challenge.

Historically, approximately 90% of combat-related deaths occur prior to a casualty reaching a medical treatment facility (MTF).^{2,3} The combat environment has many factors that affect prehospital care, including temperature and weather extremes, severe visual limitations imposed by night operations, logistical and combat-related delays in treatment and evacuation, lack of specialized medical care pro-

viders and equipment near the scene, and lethal implications of opposing forces. Thus, a tailored approach to prehospital trauma care must be used when conducting combat operations.

Combat casualty care in World War II, the Korean War, and the Vietnam War resulted in incremental and significant improvement of civilian trauma care and systems.⁴ Conversely, assimilating civilian paradigms such as Advanced Trauma Life Support into the combat setting exposed deficiencies in military prehospital trauma care during conflicts in Iraq and Somalia in the early 1990s. Subsequent congressional inquiries and after-action reports led to a better understanding of profound medical differences between civilian and military environments.⁵⁻⁹

Emerging from these reviews and from Vietnam War casualty data analysis was an

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article entitled "Tactical Combat Casualty Care in Special Operations," which presented prehospital trauma care guidelines customized for the battlefield.⁶ These Tactical Combat Casualty Care (TCCC) guidelines emphasized 3 objectives: (1) treat the patient, (2) prevent additional casualties, and (3) complete the mission. It then gave 3 phases of care: (1) care under fire, (2) tactical field care, and (3) casualty evacuation care. These centered on preventing the 3 major, potentially survivable causes of death: (1) extremity hemorrhage exsanguination, (2) tension pneumothorax, and (3) airway obstruction.^{2,3,6} Because TCCC guidelines diverged from accepted mainstream civilian standards for Advanced Trauma Life Support–based prehospital care,⁶ initial acceptance in the US military was slow despite a need for treatment protocols designed specifically for the tactical component of the combat environment.^{10,11} In contrast, Army Rangers and Navy SEALs (Sea, Air, and Land Teams) extensively implemented TCCC on its inception.¹² The TCCC guidelines have continued to evolve through a Committee on TCCC,^{13–15} founded in 2001 and currently reporting through the Defense Health Board to the Assistant Secretary of Defense for Health Affairs.

Tactical leaders are combat unit leaders at the battlefield. In 1998, a tactical leader and commander of the 75th Ranger Regiment, then COL Stanley McChrystal, instituted a directive for all Rangers to focus on 4 major training priorities termed the "Big Four": (1) marksmanship, (2) physical training, (3) small unit tactics, and (4) medical training. Thus, medical readiness immediately became a highlighted area of command interest, affording the timely opportunity to establish a casualty response system integrating initial and recurrent TCCC training into programs of instruction, training exercises, and contingency planning at all levels.^{12,16–18} This complete integration of TCCC, which included TCCC training of all assigned personnel together with tactical leader assumption of responsibility for the casualty response system, was and remains an approach that is substantially different from casualty preparedness experienced throughout the rest of the Department of Defense (DoD). Although most of the US military has now included TCCC in combat medic education, they have largely continued medical training in their previous model—lacking comprehensive, all-inclusive, command-directed casualty response systems—leaving medical care to the medics, with nominal input from tactical leaders and without continuous feedback from a registry to guide performance improvements at the combat unit level.

Although the Joint Theater Trauma System and Joint Theater Trauma Registry (JTTR) were successfully implemented to oversee process improvements in military hospital-based care and outcomes,^{19–21} a similar global approach to military prehospital care is lacking. In addition to a comprehensive command-directed TCCC training program institutionalized prior to the onset of conflict in Afghanistan and Iraq,^{12,16–18} the regiment integrated continuous performance improvement concepts. The nucleus of this approach is a Web-based prehospital trauma registry (PHTR), the only one of its kind that collects data that have historically been difficult to capture.^{7,22–24} The PHTR is a software tool specifically designed to capture

prehospital injury and treatment data with integrated features for basic analysis and instant graphing.²³ Conceptually, the PHTR was modeled after registries required at trauma centers throughout the world but was customized for data germane to the combat casualty.

We hypothesized that training the entire fighting force in TCCC, tactical leader ownership of the casualty response system, and near-real-time feedback from PHTR data would improve outcomes for combat casualties.

METHODS

A casualty is defined in this study as a member of the 75th Ranger Regiment who sustained a battle injury for which criteria were met for award of the Purple Heart medal.²⁵ Nonbattle injuries were excluded. Casualties are divided into wounded in action (WIA) and killed in action (KIA). The WIA casualties are further divided into died of wounds (DOW), returned to duty in less than 72 hours (RTD), and non-DOW and non-RTD evacuated to an MTF within 3 days.²⁶ A KIA casualty is one who died prior to reaching an MTF or is dead on arrival. A DOW casualty is one who died after reaching an MTF.

Main outcomes include potentially survivable deaths and traditional combat casualty care statistics, RTD percentage, KIA percentage, DOW percentage, and case fatality rate,²⁶ which are compared with DoD figures.²⁷ Secondary outcomes include use of TCCC treatment protocols. Independent variables include establishment of a command-directed comprehensive TCCC program with performance improvement through the PHTR. Additional hypothesis testing was accomplished using the χ^2 test of significance set at $P < .05$.

More than 8000 combat missions, primarily direct-action raids, were conducted by the 75th Ranger Regiment in Afghanistan and Iraq between October 1, 2001, and March 31, 2010. Prehospital casualty and treatment data from these missions were collected directly from medics, most within 72 hours of an event, on a Ranger Casualty Card, adopted later as DA Form 7656. Data were then entered into the PHTR and cross-referenced with other operational sources to include Purple Heart packets, casualty trackers, mission logs, medical records, JTTR data, and Armed Forces Institute of Pathology autopsies. Medical and tactical leaders scrutinized casualties for opportunities to improve care through formal investigation of data from the PHTR, JTTR, and Armed Forces Institute of Pathology. Process of care was analyzed for appropriateness and effectiveness. Casualties and treatments were critically analyzed within the context of the tactical mission. Casualties were followed to final disposition. Deaths were analyzed in detail for performance improvement opportunities. Comparisons with similar military prehospital data could not be made, as they do not exist.

Institutional review boards at the Texas A&M Health Science Center and the US Army Medical Research and Materiel Command provided approval to conduct this study.

RESULTS

Battle injury data were collected from October 1, 2001, to March 31, 2010, for Operation Enduring Freedom in Afghanistan and from March 15, 2003, to March 31, 2010, for Operation Iraqi Freedom. Casualty cards were available for 74% of casualties, JTTR data for 78% of evacuated casualties, and Armed Forces Institute of Pathology autopsy data for 100% of fatalities. Demographic, injury, and outcome data were obtained through other

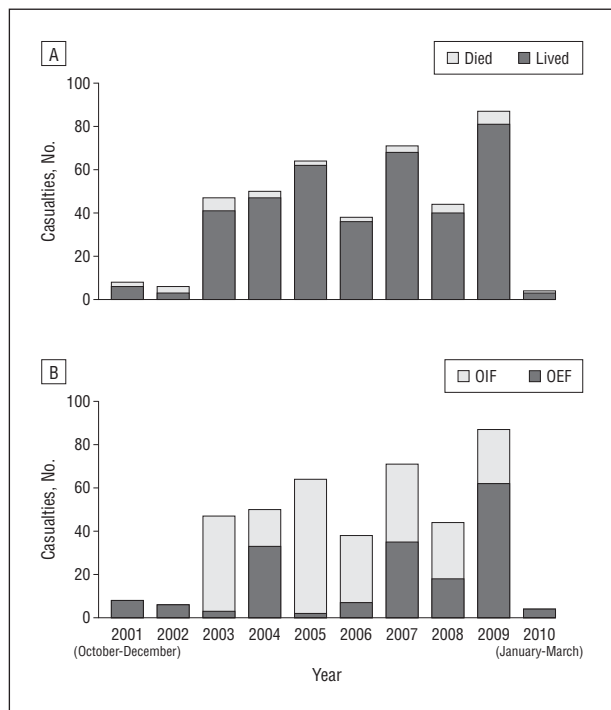


Figure 1. The 75th Ranger Regiment casualties by survival (A) and theater of operation (B) between October 1, 2001, and March 31, 2010. OIF indicates Operation Iraqi Freedom; OEF, Operation Enduring Freedom. Of the 419 casualties incurred, 32 (8%) died and 387 (92%) lived; 239 (57%) occurred in OIF and 180 (43%) occurred in OEF.

operations sources for the 26% of casualties without completed cards. By combining data sources, 100% of casualties had adequate data available for analysis. Casualties who did not seek prehospital care and medics limited by the mission accounted for missing casualty cards.

Of the 419 casualties incurred, including 239 (57%) from Operation Iraqi Freedom and 180 (43%) from Operation Enduring Freedom, 387 (92%) survived (**Figure 1**). All casualties were male, with age at time of injury ranging from 18.9 to 52.9 years. Infantrymen were most frequently injured (86%), followed by medical personnel (5%) and artillerymen (3%). Overall demographic characteristics were reflective of other military combat regiments and brigades.

Mechanisms of injury included explosions—improvised explosive device (IED) and non-IED—resulting in blast, ballistic, and blunt trauma²⁸ as well as gunshot wound injuries and aircraft and ground vehicle blunt trauma injuries. Non-IEDs were the most frequent cause of injury (43%). Gunshot wound injuries accounted for half of all deaths (**Figure 2**). None of the 32 deaths resulted from the 3 major potentially survivable causes of death (extremity hemorrhage exsanguination, tension pneumothorax, and airway obstruction) defined in the literature.^{2,3,6,29-31} One casualty with potentially survivable extremity wounds died of post-surgical complications following evacuation.

Although the DoD does not have a process to systematically evaluate potentially survivable deaths, the regiment's 3% rate (1 in 32) is significantly lower than the 24% rate (232 in 982) previously reported for a subset of US fatalities from Operation Enduring Freedom and

Operation Iraqi Freedom ($\chi^2=6.2$, $P=.01$).³¹ Benchmark statistics for RTD, KIA, DOW, and case fatality rate provided in **Table 1** and **Table 2** depict decreased combined theater and Operation Iraqi Freedom KIA and DOW rates for the 75th Ranger Regiment compared with US ground troop rates for the same period ($P<.05$). The RTD rates were lower in surviving Rangers, likely signifying increased severity of wounding.

Most interventions were for hemorrhage control (**Table 3**), 26% of which were applied by nonmedical personnel. A total of 89 tourniquets were applied to 66 casualties, with no resultant complications, which is consistent with cited safety.^{32,33} Nonmedical personnel accounted for 42% of tourniquet applications. Of casualties with tourniquets, almost all reached the next level of care alive (95%) and ultimately survived (94%). Only 16% of these survivors had injuries resulting in limb amputations, 8 with 1-limb amputation (7 below the knee and 1 below the elbow) and 2 with 2-limb amputations (3 above and 1 below the knee). A total of 37 hemostatic dressings were applied to 30 casualties, with 71% reaching the next level of care alive and ultimately surviving.

Fewer than 10% of casualties received advanced airway or breathing interventions (**Table 4**). Advanced airway procedures (intubation or cricothyroidotomy) were performed in 14 casualties in extremis, of whom 4 reached a hospital alive. Attempted intubations were converted to successful surgical airways in 3 instances, but these casualties died of their wounds prior to reaching a hospital. Advanced breathing interventions (thoracentesis or thoracostomy) were provided to 20 casualties, of whom 55% survived to reach the next level of care and 50% ultimately survived. No casualties died of airway obstruction or tension pneumothorax.

Prehospital vascular access was obtained for 90 casualties (**Table 5**), of whom 61% received intravenous fluid and 39% received vascular access only. Of casualties resuscitated with intravenous fluid, almost all reached the next level of care alive (96%) and ultimately survived (93%), with 64% receiving crystalloid, 27% colloid, and 9% both. Of casualties who received vascular access only, 91% reached the next level of care alive and also ultimately survived. Sternal intraosseous access was used in 1 casualty.

Consistent with evolving TCCC guidelines,^{6,13-15} trends over time show a decrease in intravenous fluid use and an increase in obtaining vascular access only for casualties in shock or requiring intravenous medications.

Prehospital antibiotics and analgesics were provided to reduce risk of infection and pain syndromes.^{6,13-15,34-37} A total of 113 casualties received antibiotics, including 81 who self-administered oral combat wound pill packs consisting of a fluoroquinolone and two analgesics (acetaminophen and either celecoxib or meloxicam),^{13-15,34} 28 who received parenterally administered antibiotics (75% ertapenem sodium and 25% a cephalosporin), and 4 who received both. No adverse reactions to antibiotics were reported. Of all casualties, 25 (6%) developed an infection during hospitalization. Additionally, 6% of casualties who did not receive prehospital antibiotics developed an infection, compared with 4% of those who did receive prehospital antibiotics. Most casualties with

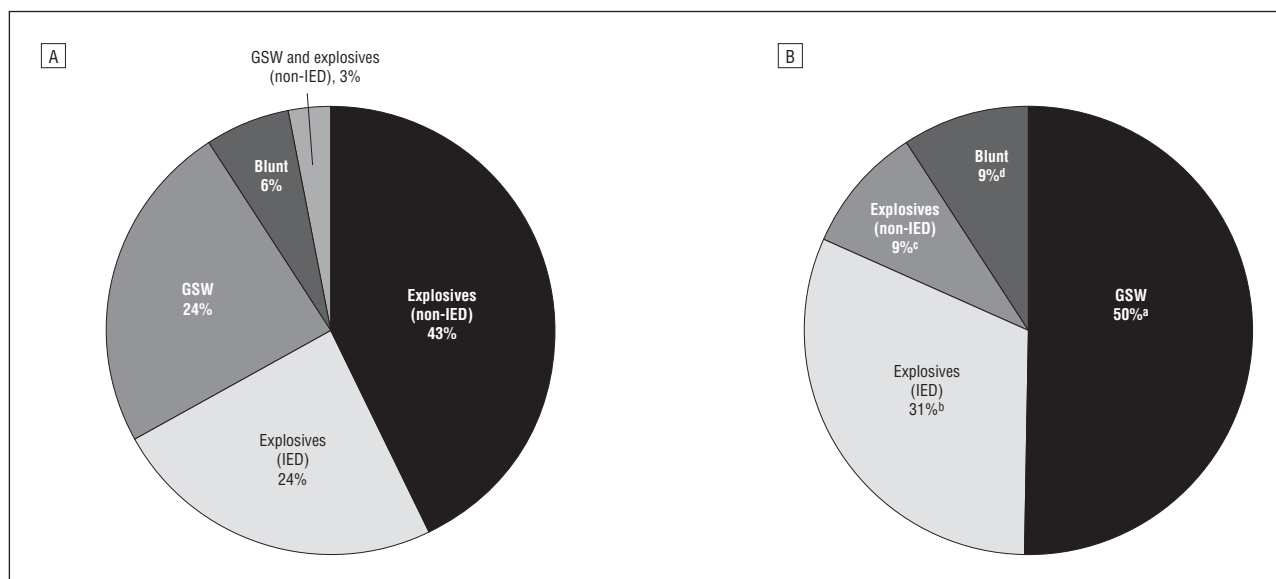


Figure 2. The 75th Ranger Regiment casualties (n=419) (A) and fatalities (n=32) (B) by mechanism of injury between October 1, 2001, and March 31, 2010. Due to rounding, percentages may not total 100%. GSW indicates gunshot wound; IED, improvised explosive device. ^aOf casualties who died of GSW injuries, 44% were from coronal trajectory transthoracic wounds, 31% were from sagittal trajectory transcranial wounds, 13% were from coronal trajectory transthoracic and neck wounds, and 6% were from sagittal trajectory extremity wounds. ^bOf casualties who died of IED injuries, all had massive head and extremity wounds and 90% also had massive torso wounds. ^cNon-IED explosives include mortars, grenades, and rocket-propelled grenades. Of casualties who died of non-IED explosive injuries, all had massive torso and extremity wounds and 33% also had massive head wounds. ^dBlunt trauma includes nonblast combat-related aircraft and vehicle incidents. Of casualties who died of blunt trauma injuries, all had massive head, torso, and extremity wounds with a crush component.

Table 1. Comparison of Battle Injuries in the 75th Ranger Regiment vs Total US Military Ground Troops Between October 1, 2001, and March 31, 2010

Theater of Operation	Casualties in 75th Ranger Regiment, No. (n=419)					Casualties in US Military Ground Troops, No. ^a (n=43 311)				
	WIA					WIA				
	Total ^b	RTD	Non-DOW and Non-RTD	DOW	KIA	Total ^b	RTD	Non-DOW and Non-RTD	DOW	KIA
OEF	167	76	89	2	13	5266	2294	2831	141	586
OIF	224	81	141	2	15	29 952	17 307	11 881	764	2478
Total	391	157	230	4	28	35 218	19 601	14 712	905	3064

Abbreviations: DOW, died of wounds; KIA, killed in action; OEF, Operation Enduring Freedom; OIF, Operation Iraqi Freedom; RTD, returned to duty in less than 72 hours; WIA, wounded in action.

^aObtained through the US Department of Defense, Defense Manpower Data Center.²⁷

^bTotal WIA=RTD + [non-DOW and non-RTD] + DOW.

an infection (80%) did not receive prehospital antibiotics. Almost all infections (96%) occurred after evacuation from the combat theater, and nearly half (48%) were cultured as *Acinetobacter*. One casualty progressed to sepsis but survived. No casualties were categorized as DOW from infection.

A total of 146 casualties received prehospital analgesics other than combat wound pill packs. These include 82 casualties who were administered oral transmucosal fentanyl citrate, 23 who received morphine sulfate, 27 who received both, and 14 who received other analgesics (hydromorphone hydrochloride, hydrocodone bitartrate, ketorolac tromethamine, or ibuprofen). Of the 50 casualties who were administered morphine, 30 (60%) received it intravenously and 20 (40%) intramuscularly. Only 1 casualty, who received oral transmucosal

fentanyl and morphine, was noted to have other-than-minimal adverse effects.³⁶

COMMENT

The Rangers are the only DoD force that has institutionalized a unitwide casualty response system using the following integrated 3-part approach: (1) TCCC training for all personnel, (2) tactical leader ownership of the prehospital casualty response system, and (3) use of PHTR data to rapidly update TCCC protocols, force health protection, and training. Focused on increasing battlefield casualty survival, this approach enables performance improvements through data-driven multidisciplinary review and consensus regarding best practices.

Table 2. Comparison of Proportional Statistics for Battle Injuries in the 75th Ranger Regiment vs Total US Military Ground Troops Between October 1, 2001, and March 31, 2010

Statistic	75th Ranger Regiment (n=419)			US Military Ground Troops (n=43 311)		
	Overall	OEF	OIF	Overall	OEF	OIF
RTD, % ^a	40 ^b	46	36 ^b	56	44	58
KIA, % ^c	10.7 ^b	12.5	9.5 ^b	16.4	16.5	16.4
DOW, % ^d	1.7 ^b	2.2	1.4 ^b	5.8	4.7	6.0
CFR ^e	7.6	8.4	7.1	10.3	12.4	10.0

Abbreviations: CFR, case fatality rate; DOW, died of wounds; KIA, killed in action; OEF, Operation Enduring Freedom; OIF, Operation Iraqi Freedom; RTD, returned to duty in less than 72 hours.

^aThe RTD percentage (RTD/wounded in action \times 100) defines minor wounds.²⁶ The differences between overall and OIF values for the 2 groups were statistically significant ($\chi^2=11.6$, $P<.001$; and $\chi^2=12.8$, $P<.001$), indicating fewer minor wounds in the Ranger populations given the same period. However, the difference between OEF values was not statistically significant ($\chi^2=0.058$, $P=.81$).

^bStatistically significant ($P<.05$).

^cThe KIA percentage $[(KIA/(KIA + wounded in action - RTD)) \times 100]$ provides a potential measure of weapon lethality, effectiveness of prehospital medical care, and availability of tactical evacuation.²⁶ All Ranger values appear to be lower compared with the US military ground troops. The differences between overall and OIF values for the 2 groups were statistically significant ($\chi^2=4.3$, $P=.04$; and $\chi^2=4.2$, $P=.04$). However, the difference between OEF values was not statistically significant ($\chi^2=0.63$; $P=.43$).

^dThe DOW percentage $[(DOW/(wounded in action - RTD)) \times 100]$ provides a potential measure of the precision of initial prehospital triage and care, optimization of evacuation procedures, and application of a coordinated trauma system as well as the effectiveness of medical treatment facility care.²⁶ Although all Ranger values appear to be lower compared with US military ground troops, only the differences in overall and OIF values were statistically significant ($\chi^2=5.9$, $P=.02$; and $\chi^2=4.2$, $P=.04$). The OEF value was not statistically significant ($\chi^2=0.71$, $P=.40$). Also of note, for US military ground troops, the DOW percentage has remained less than 5% during the past half century; however, in this study it was found to be higher overall and in OIF.

^eThe CFR $[(KIA + DOW)/(KIA + wounded in action)] \times 100$ provides a potential measure of overall battlefield lethality in a battle injury population.²⁶ Although all Ranger values appear to be lower compared with US military ground troops, none were found to be statistically significant ($\chi^2=2.5$, $P=.11$; $\chi^2=1.9$, $P=.17$; and $\chi^2=1.6$, $P=.21$).

Table 3. Hemorrhage Control Interventions Administered by 75th Ranger Regiment Personnel by Provider Level During Care Under Fire and Tactical Field Care Phases of Tactical Combat Casualty Care Between October 1, 2001, and March 31, 2010^a

Intervention	Care Provider Level, No.				Total, No.
	RFR	Nonmedic EMT	Medic	Medical Officer	
Pressure dressing ^b	33	16	136	21	206
Gauze dressing	28	16	121	23	188
Tourniquet ^c	27	10	49	3	89
Hemostatic dressing ^d	3	1	26	7	37
Total	91	43	332	54	520

Abbreviations: EMT, emergency medical technician; RFR, Ranger First Responder.

^aNonmedical personnel provided 26% (134/520) of all hemorrhage control interventions and 42% (37/89) of all tourniquets.

^bPrimarily Emergency Trauma Dressings (North American Rescue, LLC, Greer, South Carolina).

^cPrimarily Combat Application Tourniquets (Composite Resources, Rock Hill, South Carolina).

^dPrimarily HemCon bandages (HemCon Medical Technologies, Inc, Portland, Oregon) and Combat Gauze (Z-Medica Corp, Wallingford, Connecticut).

Because approximately 90% of all battlefield deaths occur prior to the casualty reaching an MTF,^{2,3} process improvements directed toward prehospital care have the best opportunity to improve survival from combat injury. Data on potentially survivable deaths from the Vietnam War suggest that 60% were from extremity hemorrhage exsanguination, 33% from tension pneumothorax, and 7% from airway obstruction.^{2,29-31} Despite widespread recognition of these causes and overall US military case fatality rate reduction from 19.1 in World War II to 15.8 in the Vietnam War to 10.3 in current conflicts described in this study, these 3 major causes of death continue to be present in Afghanistan and Iraq.^{26,30,31} Holcomb et al³⁰ identified opportunities to improve care in 12 of 82 deaths (15%) among Special Operations Forces. In a review of 982 deaths, Kelly et al³¹ reported 24% of deaths as potentially survivable, with opportunity to improve care equally distributed between prehospital and

hospital settings. Although it cannot be absolutely quantified as resulting from their casualty response system, an overall case fatality rate of 7.6 coupled with the elimination of prehospital preventable deaths validates to a notable degree the Ranger training approach (**Table 6**).

Training for TCCC was initiated by the Rangers in 1997 and formed the basis for 2 programs of instruction, Ranger First Responder (RFR) and Casualty Response Training for Ranger Leaders.^{12,16-18} Because care under fire must be simple, direct, and conditioned into the provider, RFR emphasizes repetitive hands-on application of TCCC life-saving skills incorporated into realistic scenario-based learning. Everyone on the battlefield, not just medics, has the potential to be a casualty or to be the first person to encounter a casualty; thus, RFR is mandated for all personnel in the regiment regardless of their role.¹⁸ This concept is best illustrated by the fact that 26% of hemorrhage control interventions in this study, including 42%

Table 4. Airway and Breathing Interventions Administered by 75th Ranger Regiment Personnel During Tactical Field Care Phases of Tactical Combat Casualty Care and Associated Outcomes Between October 1, 2001, and March 31, 2010

Intervention	Casualties, No.		
	WIA	DOW	KIA
Airway			
NPA only	7	0	0
King-LT intubation only ^a	0	0	2
NPA + King-LT/Combitube replaced by endotracheal intubation ^a	2	0	0
Surgical cricothyroidotomy only	1	1	5
Endotracheal intubation replaced by surgical cricothyroidotomy	0	0	3
Breathing			
Chest seal only	24	0	0
Needle thoracentesis only	2	1	0
Chest seal + needle thoracentesis	6	0	7
Chest seal + needle thoracentesis + tube thoracostomy	2	0	2

Abbreviations: DOW, died of wounds; KIA, killed in action; NPA, nasopharyngeal airway; WIA, wounded in action.

^aThe King-LT is from King Systems, Noblesville, Indiana; the Combitube is from Kendall-Sheridan Catheter Corp, Argyle, New York.

Table 5. Vascular Access and Intravenous Fluid Administered by 75th Ranger Regiment Personnel During Tactical Field Care Phases of Tactical Combat Casualty Care Between October 1, 2001, and March 31, 2010

Intervention	IVF Dose, mL	Casualties, No.
Saline lock only	NA	35
Saline lock and IVF	NA	55
Normal saline	250	1
	500	25 ^a
	1000	6
	1500	1
Hextend ^b	250	2
	500	12 ^{a,c}
	1000	1
Normal saline + Hextend ^b	500 + 500	3
	1000 + 250	1
	500 + 100	1 ^a
Lactated ringers	500	2 ^a

Abbreviations: IVF, intravenous fluid; NA, not applicable.

^aFour casualties received 2 saline locks and IVF.

^bHextend is from Hospira, Inc, Lake Forest, Illinois.

^cOne casualty received IVF through a FAST-1 sternal intraosseous device (Pyng Medical Corp, Richmond, British Columbia, Canada).

Table 6. Tactical Combat Casualty Care Training in the 75th Ranger Regiment

Title	Who	Training
Ranger First Responder	All personnel	Initial and annual TCCC point-of-wounding training emphasizing hemorrhage control
Casualty battle drills	All personnel	Casualty care and evacuation rehearsals integrated into tactical training
Casualty response training for Ranger leaders	All small unit leaders and commanders	Contingency planning and management of casualty response and evacuation procedures
EMT-B program	Nonmedics (1 in 10 personnel)	4-wk civilian EMT-B course with refresher training that includes TCCC and Prehospital Trauma Life Support training
Ranger medic	Medics (1 in 30 personnel)	Assigned personnel who have completed a 16-wk US Army combat medic training program and an EMT-P or 26-wk Special Operations Combat Medic training program

Abbreviations: EMT-B, Emergency Medical Technician Basic; EMT-P, Emergency Medical Technician Paramedic; TCCC, Tactical Combat Casualty Care.

of tourniquets, were applied by nonmedical personnel at the point of wounding, probably decreasing the necessity for additional prehospital resuscitation and certainly contributing to no preventable deaths due to extremity hemorrhage exsanguination.

Because the tactical commander manages all resources dedicated to preparing for and completing a mission, it is this nonmedical leader who is ultimately responsible for the prehospital casualty response system. This concept differentiates RFR and Casualty Response

Training for Ranger Leaders from other medical programs. The goal is to educate all on the operational consequences of a casualty and how to mitigate adverse outcomes for both the casualty and the mission. A key underpinning of this training is the use of the term *casualty response* rather than *medical training*, as it imparts a collective requirement for the entire fighting force to take action as with any other battle drill. When a casualty occurs on a mission, the event is a tactical problem to be solved and not just an isolated medical issue.

Casualty battle drills are imbedded into small unit tactics and tactical training exercises. Realism is maximized by introducing the turbulence of casualty scenarios into the natural flow of tactical training. Mastery of this training instills confidence in the casualty response system, increasing unit morale and cohesion as all come to realize that the best possible care will be provided promptly by fellow soldiers on the battlefield, thus putting medical capability on par with fighting capability.

Medical training in the DoD is not consistent among the services and between units. In the US Army, a centralized 16-week medical course is used to initially train combat medics. Thereafter, sustainment medical training, tactical training, and employment of combat medics are decentralized and the responsibility of the individual line commander. Tactical line commanders who understand the requirements and importance of the casualty response system will provide the time, training, and equipment necessary to ensure that medical personnel, and ultimately all assigned personnel, are sufficiently prepared to receive combat casualties. This is not the norm, however, as many do not realize this responsibility or recognize the operational importance of casualty care.

A standardized Ranger medic training pathway was initially established in 1998.¹⁶ This pathway was refined to include Emergency Medical Technician Paramedic or 26-week Special Operations Combat Medic³⁸ training followed by recurrent sustainment, assessment, and validation training that maximizes use of human patient simulators, live tissue training, realistic trauma lanes, and major metropolitan trauma center rotations. To provide a foundation for medic knowledge, the first official *Ranger Medic Handbook* was distributed throughout the regiment in 2001.¹⁷ This TCCC-based handbook, updated periodically,³⁹ provides medics with guidelines, protocols, and procedures for optimizing prehospital care.

A 4-week Emergency Medical Technician Basic program was mandated for 1 in 10 nonmedics as a means to bridge the gap between RFRs and Ranger medics.¹⁸ Recurrent sustainment training includes the Prehospital Trauma Life Support course, as this course has evolved to include military and TCCC-based protocols and procedures.¹⁵ This Emergency Medical Technician Basic program not only expanded medical capabilities, it also created more medically knowledgeable tactical leaders as they advanced through the leadership ranks.

In the regiment, it is now common and expected for nonmedical personnel to rapidly and accurately manage life-threatening extremity hemorrhage. This immeasurably improves tactical leader awareness and responsibility for their casualty response system. Tactical leaders now hold themselves accountable for casualties and ca-

sualty response training through self-assessment and unit status reports. Demonstrated medical proficiency is regarded to be as important as weapon proficiency. Well-informed nonmedical leaders may ultimately play the most important role in reducing preventable death on the battlefield. In fact, intensive training, contingency planning, and an appropriate tactical response to casualty scenarios may have saved more lives than the medical interventions themselves.

Prehospital record keeping and the availability of such data are notoriously challenging on the battlefield.^{7,24} In 2001, the regiment began work on a minimalistic data set captured through a Ranger Casualty Card collection program. The template for this card was adopted by the US Army in 2009 as DA Form 7656 TCCC Casualty Card. With direct support from Congress, funds were allocated for a combat trauma registry modeled after trauma registry concepts developed during the past 40 years in the civilian sector.^{40,41} The hospital effort centered on inpatient medical treatment facilities through the JTTR,¹⁹⁻²¹ and the prehospital effort centered on a tactical unit through the PHTR.^{22,23}

The primary purpose of the PHTR is to provide tactical leaders and medical care providers with near-real-time trends, reports, and analysis for lessons learned, quality assurance, and performance improvements designed to immediately reduce morbidity and mortality on the battlefield. Commanders quickly make data-based decisions to optimize casualty response and force protection, resulting in rapid treatment protocol modification and body armor evolution. Resultant directed procurement of medical devices and personal protective equipment is data driven, peer reviewed, and cost-effective.

CONCLUSIONS

Historically, war and conflict have prompted advances in both individual techniques and effective systems to improve trauma care.⁴²⁻⁴⁴ The current war is no exception. Prehospital advances implemented by TCCC have improved the probability that casualties will arrive at the hospital alive so they can benefit from the trauma care system now in place.^{13-15,32,33,45-47} However, not all opportunities have been realized. The remaining challenge is to refine performance improvements and best practices through systemwide prehospital data collection.

The TCCC guidelines represented a paradigm shift away from civilian prehospital care practices. The casualty response system described in this study is also a shift away from traditional US military practices. Despite the lethality of modern-day warfare, the 75th Ranger Regiment's implementation of a comprehensive casualty response system sustained by focused training directed by tactical leaders using data from a unit-based PHTR has resulted in historically low casualty rates for a frontline unit of its type, to include virtual elimination of preventable combat death. This approach has been recommended by the Defense Health Board for implementation by combatant units throughout the DoD.⁴⁸

Performance improvements in prehospital care are actively migrating from the current battlefield to civilian

practice. Implementing these initiatives in concert with detailed documentation and analysis may have profound implications for civilian prehospital trauma training, care, and preventable death, especially in light of the fact that equivalent epidemiological studies on potentially survivable death from trauma in the civilian prehospital environment are sparse, and none have documented a pathway for successful elimination of preventable death. A civilian prehospital system that integrates first responder skills throughout a community and enacts performance improvement through a registry may also eliminate preventable death.

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Additional Information: This article is dedicated to SFC Marcus V. Muralles, a former 75th Ranger Regiment Special Operations Combat Medic who was killed in action while serving with the 160th Special Operations Aviation Regiment in Afghanistan on June 28, 2005, and SGT Jonathan K. Peney, a Special Operations Combat Medic who was killed in action while serving with the 75th Ranger Regiment in Afghanistan on June 1, 2010.

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REFERENCES

1. US Army. Overview of 75th Ranger Regiment. <http://www.goarmy.com/ranger.html>. Accessed September 13, 2010.
2. Bellamy RF. The causes of death in conventional land warfare: implications for combat casualty care research. *Mil Med*. 1984;149(2):55-62.
3. Champion HR, Bellamy RF, Roberts CP, Leppaniemi A. A profile of combat injury. *J Trauma*. 2003;54(5)(suppl):S13-S19.
4. Champion HR, Ochsner MG, Bellamy R. Surgical care of victims of conflict. In: Moore E, Feliciano D, Mattox K, eds. *Trauma*. 5th ed. New York, NY: McGraw-Hill; 2004:1161-1193.
5. Trunkey DD. Lessons learned. *Arch Surg*. 1993;128(3):261-264.
6. Butler FK Jr, Hagmann J, Butler EG. Tactical combat casualty care in special operations. *Mil Med*. 1996;161(suppl):3-16.
7. Mabry RL, Holcomb JB, Baker AM, et al. United States Army Rangers in Somalia: an analysis of combat casualties on an urban battlefield. *J Trauma*. 2000;49(3):515-529.
8. Holcomb JB, Jenkins D, Rhee P, et al. Damage control resuscitation: directly addressing the early coagulopathy of trauma. *J Trauma*. 2007;62(2):307-310.
9. Trunkey DD, Johannigman JA, Holcomb JB. Lessons relearned. *Arch Surg*. 2008;143(2):112-114.
10. Bellamy RF. How shall we train for combat casualty care? *Mil Med*. 1987;152(12):617-621.
11. Baker MS. Advanced trauma life support: is it adequate stand-alone training for military medicine? *Mil Med*. 1994;159(9):587-590.
12. Butler FK Jr. Tactical medicine training for SEAL mission commanders. *Mil Med*. 2001;166(7):625-631.
13. Butler FK Jr, Holcomb JB, Giebner SD, McSwain NE, Bagian J. Tactical combat casualty care 2007: evolving concepts and battlefield experience. *Mil Med*. 2007;172(11)(suppl):1-19.
14. Butler FK. Tactical combat casualty care: update 2009. *J Trauma*. 2010;69(suppl 1):S10-S13.
15. National Association of Emergency Medical Technicians. *Prehospital Trauma Life Support*. 7th military ed. St Louis, MO: Mosby; 2011.
16. Pappas CG. The Ranger medic. *Mil Med*. 2001;166(5):394-400.
17. Kotwal RS, Miller RM, Montgomery HR. *Ranger Medic Handbook 2001*. Fort Benning, GA: Fort Benning Publications; 2001.
18. Veliz CE, Montgomery HR, Kotwal RS. Ranger first responder and the evolution of tactical combat casualty care. *J Spec Oper Med*. 2010;10(3):90-91.
19. Eastridge BJ, Jenkins D, Flaherty S, Schiller H, Holcomb JB. Trauma system development in a theater of war: experiences from Operation Iraqi Freedom and Operation Enduring Freedom. *J Trauma*. 2006;61(6):1366-1373.
20. Eastridge BJ, Costanzo G, Jenkins D, et al. Impact of joint theater trauma system initiatives on battlefield injury outcomes. *Am J Surg*. 2009;198(6):852-857.
21. Eastridge BJ, Wade CE, Spott MA, et al. Utilizing a trauma systems approach to benchmark and improve combat casualty care. *J Trauma*. 2010;69(suppl 1):S5-S9.
22. Kotwal RS, Meyer DE, O'Connor KC, et al. Army Ranger casualty, attrition, and surgery rates for airborne operations in Afghanistan and Iraq. *Aviat Space Environ Med*. 2004;75(10):833-840.
23. Kotwal RS, Montgomery HR, Mechler KK. A prehospital trauma registry for tactical combat casualty care. *US Army Med Dep J*. 2011:15-17.
24. Eastridge BJ, Mabry RL, Blackburne LH, Butler FK. We don't know what we don't know: prehospital data in combat casualty care. *US Army Med Dep J*. 2011:11-14.
25. Headquarters, Department of the Army. Army regulation 600-8-22: military awards, paragraph 2-8. Washington, DC: Headquarters, Department of the Army; 2006.
26. Holcomb JB, Stansbury LG, Champion HR, Wade C, Bellamy RF. Understanding combat casualty care statistics. *J Trauma*. 2006;60(2):397-401.
27. Statistical Information Analysis Division, Defense Manpower Data Center, US Department of Defense. Operation Iraqi Freedom casualty summary by type and Operation Enduring Freedom casualty summary by type. <http://siadapp.dmdc.osd.mil/personnel/CASUALTY/castop.htm>. Accessed September 27, 2010.
28. DePalma RG, Burris DG, Champion HR, Hodgson MJ. Blast injuries. *N Engl J Med*. 2005;352(13):1335-1342.
29. Maughon JS. An inquiry into the nature of wounds resulting in killed in action in Vietnam. *Mil Med*. 1970;135(1):8-13.

30. Holcomb JB, McMullin NR, Pearse L, et al. Causes of death in US Special Operations Forces in the global war on terrorism: 2001-2004. *Ann Surg.* 2007; 245(6):986-991.
31. Kelly JF, Ritenour AE, McLaughlin DF, et al. Injury severity and causes of death from Operation Iraqi Freedom and Operation Enduring Freedom: 2003-2004 vs 2006. *J Trauma.* 2008;64(2)(suppl):S21-S27.
32. Kragh JF Jr, Walters TJ, Baer DG, et al. Practical use of emergency tourniquets to stop bleeding in major limb trauma. *J Trauma.* 2008;64(2)(suppl):S38-S50.
33. Kragh JF Jr, Walters TJ, Baer DG, et al. Survival with emergency tourniquet use to stop bleeding in major limb trauma. *Ann Surg.* 2009;249(1):1-7.
34. Butler FK, O'Connor KC. Antibiotics in tactical combat casualty care 2002. *Mil Med.* 2003;168(11):911-914.
35. Gerhardt RT, Matthews JM, Sullivan SG. The effect of systemic antibiotic prophylaxis and wound irrigation on penetrating combat wounds in a return-to-duty population. *Prehosp Emerg Care.* 2009;13(4):500-504.
36. Kotwal RS, O'Connor KC, Johnson TR, Mosely DS, Meyer DE, Holcomb JB. A novel pain management strategy for combat casualty care. *Ann Emerg Med.* 2004;44(2):121-127.
37. Holbrook TL, Galarneau MR, Dye JL, Quinn K, Dougherty AL. Morphine use after combat injury in Iraq and post-traumatic stress disorder. *N Engl J Med.* 2010; 362(2):110-117.
38. Wheeler LW, McNeil ME, Campbell MD, Lasko MJ, Yakel DJ. Trauma training. *Spec Warf.* 2010;23(3):6-9.
39. Kotwal RS, Montgomery HR, Hammesfahr JF. *Ranger Medic Handbook 2007.* Las Vegas, NV: Cielo Azul; 2007.
40. Trunkey DD. Trauma centers and trauma systems. *JAMA.* 2003;289(12):1566-1567.
41. MacKenzie EJ, Hoyt DB, Sacra JC, et al. National inventory of hospital trauma centers. *JAMA.* 2003;289(12):1515-1522.
42. Gawande A. Casualties of war: military care for the wounded from Iraq and Afghanistan. *N Engl J Med.* 2004;351(24):2471-2475.
43. Peake JB. Beyond the Purple Heart: continuity of care for the wounded in Iraq. *N Engl J Med.* 2005;352(3):219-222.
44. Pruitt BA Jr. Combat casualty care and surgical progress. *Ann Surg.* 2006;243(6): 715-729.
45. Mabry RL, McManus JG. Prehospital advances in the management of severe penetrating trauma. *Crit Care Med.* 2008;36(7)(suppl):S258-S266.
46. Cordts PR, Brosch LA, Holcomb JB. Now and then: combat casualty care policies for Operation Iraqi Freedom and Operation Enduring Freedom compared with those of Vietnam. *J Trauma.* 2008;64(2)(suppl):S14-S20.
47. Tien HC, Jung V, Rizoli SB, Acharya SV, MacDonald JC. An evaluation of tactical combat casualty care interventions in a combat environment. *J Am Coll Surg.* 2008;207(2):174-178.
48. US Department of Defense. Defense Health Board memorandum: Tactical Combat Casualty Care and minimizing preventable fatalities in combat. August 6, 2009.